Electrical Conductivity of Aqueous Solutions

Objectives

The objectives of this laboratory are:

a) To observe electrical conductivity of substances in various aqueous solutions
b) To determine of the solution is a strong or weak electrolyte
c) To interpret a chemical reaction by observing aqueous solution conductivity.

Background

Electrical conductivity is based on the flow of electrons. Metals are good conductors of electricity because they allow electrons to flow through the entire piece of material. Thus, electrons flow like a "sea of electrons" through metals. In comparison, distilled water is a very poor conductor of electricity since very little electricity flows through water. Highly ionized substances are **strong electrolytes**. Strong acids and salts are strong electrolytes because they completely ionize (dissociate or separate) in solution. The ions carry the electric charge through the solution thus creating an electric current. The current, if sufficient enough, will light one or both LEDs on a *conductivity meter*, shown at right.

Slightly ionized substances are **weak electrolytes**. Weak acids and bases would be categorized as weak electrolytes because they do not completely dissociate in solution.

Substances that do not conduct an electric current are called **non-electrolytes**. Non-electrolytes do not ionize; they do not contain moveable ions. The LEDs of a conductivity meter will not light because there are no ions to carry the electric current. The table below lists examples of strong, weak and non-electrolytes.

Strong Electrolytes

Strong Acids

Hydrochloric acid	HCl (aq)
Hydrobromic acid	HBr (aq)
Hydroiodic acid	HI (aq)
Nitric acid	HNO_3 (aq)
Sulfuric acid	H_2SO_4 (aq)
Perchloric acid	$HClO_4$ (aq)
Chloric acid	$HClO_3$ (aq)

Strong Bases

Sodium hydroxide	NaOH (aq)
Potassium hydroxide	KOH (aq)
Calcium hydroxide	$Ca(OH)_2$ (aq)
Barium hydroxide	$Ba(OH)_2$ (aq)

Soluble Salts

Sodium chloride	NaCl (aq)
Potassium carbonate	K_2CO_3 (aq)
Copper(II) sulfate	$CuSO_4$ (aq)

Weak Electrolytes

Weak Acids

Acetic acid	$HC_2H_3O_2$ (aq)
Carbonic acid	H_2CO_3 (aq)
Citric acid	$C_6H_8O_7$ (aq)
Phosphoric acid	H_3PO_4 (aq)

Weak Bases

Ammonia	NH_3 (aq)
Ammonium hydroxide	NH_4OH (aq)
Magnesium hydroxide	$Mg(OH)_2$ (aq)
Most other bases	

Slightly Soluble Salts

Silver chloride	AgCl (s)
Calcium carbonate	$CaCO_3$ (s)
Barium sulfate	$BaSO_4$ (s)

Non-Electrolytes

Distilled water	H_2O (l)
Methanol	CH_3OH (aq)

Procedure

Safety

Be cautious with hydrochloric acid, nitric acid, sulfuric acid and concentrated acetic acid. Although low in concentration, some individuals may have extreme skin sensitivities. If you experience any tingling sensations or skin discolorations, rinse immediately with large amounts of water for 15 minutes. Inform your instructor ASAP.

Personal Protective Equipment (PPE) required: lab coat, safety goggles, closed-toe shoes

Materials and Equipment

conductivity meter, wash bottle with distilled water, large beaker for rinsing/waste, small beakers, Kimwipes, solid sodium chloride, solid calcium carbonate

Solutions: acetic acid, aluminum nitrate, ammonium hydroxide, calcium hydroxide, citric acid, ethanol, hydrochloric acid, magnesium hydroxide, magnesium sulfate, nitric acid, potassium iodide, sodium chloride, sodium hydroxide, sucrose

Conductivity Testing – Evidence for Ions in Aqueous Solution

1. The meter has a 9V battery, and two parallel copper electrodes.
   Use a wash bottle with distilled water and a large beaker labeled "waste" to rinse the copper electrodes. Dry using a Kimwipe tissue. When switched on, the lights should not be lit any color. If they are, repeat the rinsing and drying.

NOTE: DO NOT EXPOSE THE CIRCUIT BOARD TO WATER. Only the copper electrodes should be rinsed with water.

2. Place the meter so that the circuit board is facing up (the battery will be below). Always place the meter in this way so that the circuit board will not get wet. On this side, there is a guide to the possible conductivity measurements:

Scale	Red LED	Green LED	Conductivity
0	off	off	low or none
1	dim	off	low
2	medium	off	medium
3	bright	dim	high
4	very bright	medium	very high

Switch the meter on and dip the copper electrodes to test conductivity. Thoroughly rinse with distilled water after each test, and dry with Kimwipes. Switch the meter off between uses.

3. Place 5 mL of *distilled water* into a small, clean beaker. Test and record your results.

4. Place 5 mL of *tap water* into a small, clean beaker. Test and record your results.

5. Place about 0.2 g of solid sodium chloride (NaCl) into a small, clean beaker and test the conductivity. Add 5 mL distilled water to the sodium chloride; test the conductivity of the solution. Dispose of this solution in the sink and rinse the beaker.

6. Place about 0.2 g of solid calcium carbonate ($CaCO_3$) into a small, clean beaker and test the conductivity. Add 5 mL distilled water to the calcium carbonate; test the conductivity of the solution. Dispose this solution in the sink and rinse the beaker.

7. Use 5 mL of each of the following in 100-mL beaker to test the conductivities.

   Be sure to rinse and dry the electrodes between tests, using your wash bottle with waste beaker, and Kimwipes.

   Dispose the solution and rinse the beaker in the sink between tests. Dispose the waste beaker solution in non-hazardous waste in the hood.

   a. acetic acid, 0.1 M $HC_2H_3O_2$
   b. aluminum nitrate, 0.1 M $Al(NO_3)_3$
   c. ammonium hydroxide, 0.1 M NH_4OH (aq)
   d. calcium hydroxide, saturated $Ca(OH)_2$
   e. citric acid, 0.1 M $C_6H_8O_7$
   f. ethanol, CH_3CH_2OH
   g. hydrochloric acid, 0.1 M HCl
   h. magnesium hydroxide, saturated $Mg(OH)_2$
   i. magnesium sulfate, 0.1 M $MgSO_4$
   j. nitric acid, 0.1 M HNO_3
   k. potassium iodide, 0.1 M KI
   l. sodium chloride, 0.1 M NaCl
   m. sodium hydroxide, 0.1 M NaOH
   n. sucrose, 0.1 M $C_{12}H_{22}O_{11}$